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THE RECORDING AND PRELIMINARY ANALYSIS OF A DATA BASE FOR THE A--ETC(U)
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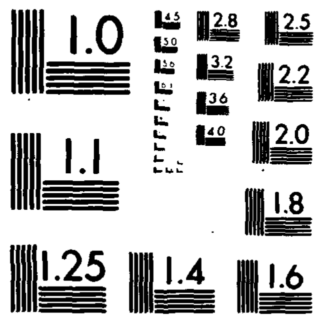

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(6) THE RECORDING AND PRELIMINARY ANALYSIS OF A DATA BASE FOR THE ASSESSMENT OF 'STRAIN' IN AIR TRAFFIC CONTROLLERS, USING SPEECH.

by

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(12) 24

SUMMARY

A data base of Air Traffic Controllers' verbal communications during periods of high and low activity was tape recorded during the Farnborough International Airshow in 1978. A description of the data base is given together with the activity measures used. The data base was obtained to provide a means of testing the hypothesis that the speech signal can be used to assess 'strain' or the effects of increasing 'stress' in work. Preliminary statistical analysis of the voice 'pitch' of one of the controllers has shown that periods of high and low activity may be readily discriminated using several 20 second segments of voiced speech.

page -1-

320450

LIST OF CONTENTS

FS 334

1 INTRODUCTION

The potential use of speech in the assessment of 'strain' in a man at work has been discussed in some detail by the author in Ref 1. The reader is referred to this Report for a definition of terms used by the author (*eg* 'stress' and 'strain') and for background in the characteristics of speech. Ideally the present report should be read in conjunction with Ref 1. One of the potentially most useful parameters of speech for assessing 'strain' is the voice fundamental frequency (referred to hereafter as 'pitch'). In order to investigate and quantify any changes in voice 'pitch' characteristics due to increasing mental workload, which may result in increased 'strain', a suitable data base was required. Such a data base would contain sufficient speech of a number of subjects under varying workloads to enable meaningful statistical measures of 'pitch' changes to be estimated (*eg* mean and standard deviation). Air Traffic Controllers (ATCs) would seem to be ideal candidates for providing such a data base since their task requires them to communicate by speech and may at times be very demanding. It was decided that the Farnborough International Airshow (1978) would be a suitable venue for recording ATCs at work where it was envisaged that periods of low and very high activity could be recorded.

In order to enable changes of the voice 'pitch' characteristics to be correlated with workload level or task difficulty, an independent activity measure was used. The purpose of this report is to describe the data base and the activity measure used, and to present the preliminary results of 'pitch' analysis on one of the ATCs recorded.

2 DESCRIPTION OF THE DATA BASE

ATCs at two radar and the tower positions were recorded over a period of four days from 4-7 September. Recordings were made on some of the mornings and on all afternoons commencing at around 1700 hours, after the flying display. Most controllers varied their position from day to day, some positions being busier than others. The busiest position was expected to be the tower immediately after the official flying display when demonstration flights would be required and VIPs would be leaving Farnborough and Blackbushe Airport by helicopter and light plane. Recordings were made by tapping into the microphone and incoming RT lines outside the controller's positions to avoid the distracting presence of other staff. NAGRA 4SJ portable tape recorders were used at a tape speed of $1\frac{7}{8}$ inches per second. The frequency response at this speed was considered adequate for subsequent 'pitch' tracking. A total of ten ATCs were recorded over the four day period, providing nearly

23 hours of material. However, because the rota for each ATC position was outside the control of the team making the recordings, only one ATC produced a sufficiently large and suitable data base representing periods of high and low activity. This was disappointing since it was hoped that several controllers could be used in the following studies to give greater significance to the results. The controller used in the study invariably occupied the Tower position which proved, as expected, to be the busiest of all those recorded, during the late afternoon after the flying display. Nearly 8 hours of recordings were made of this controller. This controller was used for all the 'pitch' analysis described in section 4.

3 ACTIVITY MEASURES

In order to attempt to correlate overall changes in the 'pitch' of the ATC's voice with varying work levels or task demands some independent measure of the work level was required. Through consultation with the Air Traffic Control Evaluation Unit (ATCEU) at Hurn Airport the activity measure described below was adopted. ATCEU have found this measure to be a useful method of monitoring and quantifying the ATC's workload.

The activity measure is simply a record of the number of RT communications between the controller and the aircraft, the number of telephone communications and the number of Direct Voice Liaison (DVL) messages between controllers in successive 5 minute periods. These records can then be tabulated and an activity histogram drawn up with the number of aircraft movements in each 5 minute period (see Fig 1). The number of messages was monitored either in real time using coding sheets (Fig 2) or subsequently from the tape recording. On the afternoon and early evening of 6 September a total of 109 aircraft movements were recorded during a 90 minute period, a particularly high figure for ATC operations.

These activity measures have the recognised weakness, however, of being misleading in the case where a controller may not be controlling a large number of aircraft at a particular time, but has a difficult problem with one or more aircraft. In this case the record of the number of messages may be low but the controller may be under a high mental workload. Caution must therefore be exercised in interpreting these activity measures. It is to be expected that speech analysis, and perhaps 'overall pitch' changes in particular, may provide a useful measure of the 'strain' due to the workload in this situation where the activity measure on its own would fail.

4 VOICE PITCH ANALYSIS - PRELIMINARY RESULTS

The reader is referred to Ref 1 for a discussion on 'pitch' tracking and methods. It is not the purpose of this report to describe or discuss the techniques which can be used for pitch tracking. The rationale behind the use of voice pitch for the assessment of 'strain', or the effects of varying mental workloads is also discussed in Ref 1. In order to produce statistical parameters of the voice 'pitch', such as mean and standard deviation, at least 20 seconds of voiced speech is required[2]. Since speech is not composed entirely of voiced sounds (where 'pitch' is present) and the controller is not speaking continuously, several minutes or more of recording may be required to produce a single estimate of the mean and standard deviation of the voice 'pitch'. Before any significance can be attached to differences in the means or standard deviations of various estimates, ideally a large number of estimates are required - hence the requirement for a large data base, preferably with many speakers. Unfortunately as mentioned previously the requirements were not met for more than one controller in this exercise and only one controller could be selected to test the potential of 'pitch' tracking and analysis in assessing 'strain' or the effects of workload.

The preliminary analysis was carried out using the facilities of the Joint Speech Research Unit (JSRU), Cheltenham since the author's 'pitch' tracker[1] had not, at the time, been interfaced to a computer facility. A Cepstrum processor (Ref 1, p 12) interfaced to a PDP11/40 computer was used to process the tapes. Before processing recordings made at the Tower position on 6 and 7 September, the tapes were edited by hand to remove any unwanted speech from other controllers or pilots speaking to the Tower controller. The material was divided into two categories, periods of low and high activity, as assessed from the activity measures described in section 3. Recordings made on the morning of 7 September provided the low activity material and recordings made in the afternoons of the 6 and 7 September, the high activity material (Figs 1 and 3). The 'pitch' from as many 20 second segments of voiced speech as possible was extracted from the recordings using the Cepstrum processor. Data for each segment were stored and labelled on the computer for subsequent statistical analysis.

Various statistical parameters were computed for each segment but it was decided beforehand that only the mean and mean absolute deviation would be used initially since previous work (cited in Ref 1) has indicated that these parameters are likely to be the most significant in identifying changes in 'pitch' due to 'strain'. Hecker *et al*[3] for example, found an overall increase in mean 'pitch' and a *decrease in 'pitch' range* under 'task induced stress'. From the physiological standpoint there is evidence to suggest that an increase in laryngeal muscle tension and/or an increase in sub-glottal pressure (pressure below the vocal cords) gives rise to changes in 'pitch'[4,5]. Such physiological changes may well occur under certain levels of task induced 'stress' or mental workload.

The mean absolute deviation was used rather than standard deviation since it is less sensitive to outlying points (erroneous 'pitch' values produced by the Cepstrum processor, *eg* 'pitch' doubling).

A scatter plot of the mean 'pitch' versus the mean absolute deviation for all the segments, representing both high and low activity, is shown in Fig 4. No suitable statistical measure was found to demonstrate the significance. However, it is fairly clear that two distinct clusters exist in the scatter plot enabling the periods of high and low activity to be discriminated. The data appears to be highly uncorrelated in the mean 'pitch' axis with only two points from the total of 21 overlapping. The overall mean and mean absolute deviation for both classes turns out to be 159 Hz with a mean absolute deviation of 25.8 Hz for the low activity class and 174 Hz with a mean absolute deviation of 20.6 Hz for the high activity class.

These results agree with the findings of Hecker *et al*[3] in their experiments on the 'manifestations of task induced stress in the acoustic speech signal'. Several subjects investigated by this group showed an overall increase in 'pitch' and a tendency to speak in more of a monotone (*ie* a decrease in mean absolute deviation) when they were under task induced stress.

Other work carried out by Williams and Stevens (both members of the team involved in the previous experiments) on the effects of emotion on speech, particularly of pilots in flight, has shown an increase in median 'pitch' and 'pitch' range for several seconds of speech recorded in situations of fear[6,7]. It is postulated that this may be a result of a lack of motor control and possibly tremor[6]. The fact that in this instance the 'pitch' range has increased rather than decreased as in the case of 'task induced stress', illustrates the need for caution in relating work done on changes in speech under different kinds of emotion to possible changes which may occur under mental workload or 'task induced stress'. It should be said also that the observations made by Williams and Stevens[6] were made in situations of extreme emotion prior to fatal air crashes and the 'pitch' changes were larger than those reported in this study. It could however be speculated that the large variations in 'pitch' range observed in situations of fear and anxiety may be observed in high levels of mental workload or 'task induced stress' where the subject may lose complete control of the situation.

The effects on 'pitch' reported in this study and that of Hecker *et al*[3] may represent an intermediate stage where a subject is 'stressed' but in control of the situation. It is possible, that if this were true, measurement of 'pitch' characteristics may provide a useful tool for investigating the limit of acceptable workload.

In the present study a number of other speakers would be required to establish statistically the significance of these observations. However, the observations outlined above are sufficiently encouraging to suggest that voice 'pitch' analysis may provide a useful method, either on its own or combined with other methods, of assessing mental workload and 'strain' in ATCs or other subjects whose task requires speech communication.

5 CONCLUSIONS

A data base of ATC communications during periods of low and high controller activity has been collected. The exercise has illustrated the problems of obtaining a large data base using a number of speakers in an operational environment. Preliminary analysis of the voice pitch of one ATC occupying the Tower position over two consecutive days has shown that periods of high and low activity, as measured by an independent activity measure, can be distinguished by changes in mean voice 'pitch' and mean absolute deviation. Further analysis with more subjects needs to be carried out to establish the consistency with which voice pitch changes may be used to assess mental workload and 'strain'. The small study reported here, has, however revealed the potential of speech analysis and 'pitch' changes in particular for assessing mental workload and 'strain'.

Acknowledgments

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FS 334

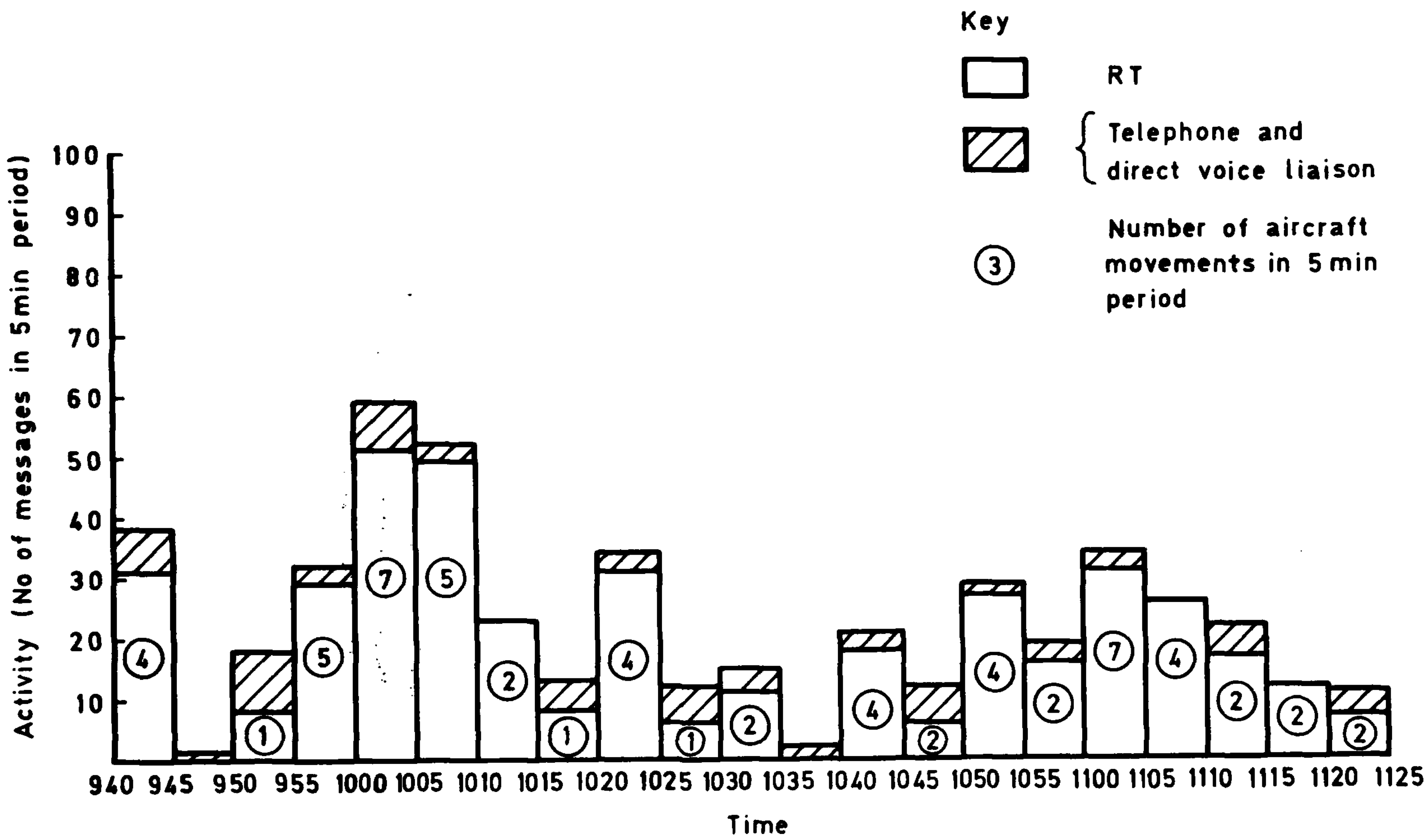

Fig 1 Activity histogram — tower position am 7-9-78 (low activity)

Fig 1

Fig 2

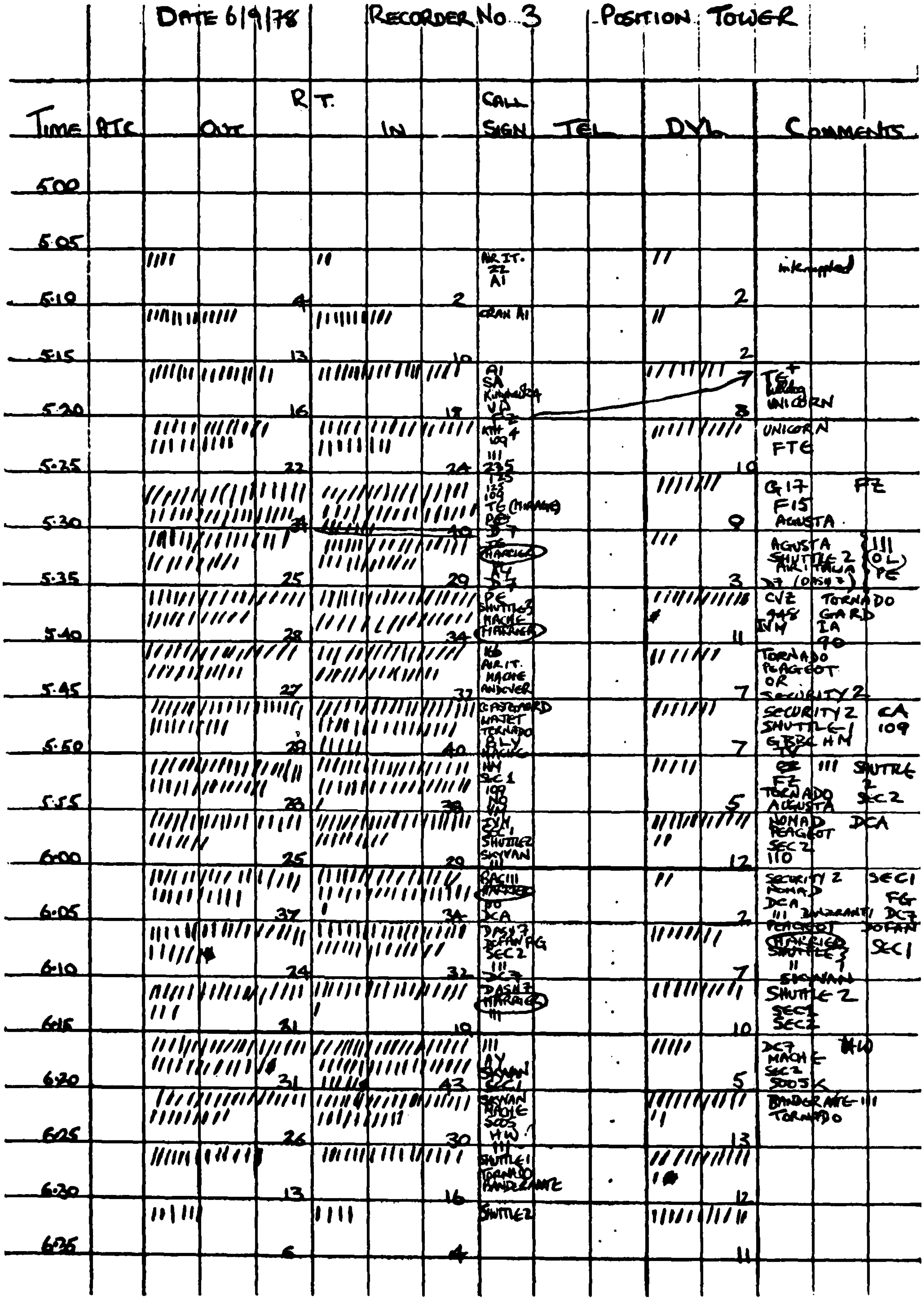

Fig 2 Example of coding sheet

FS 334

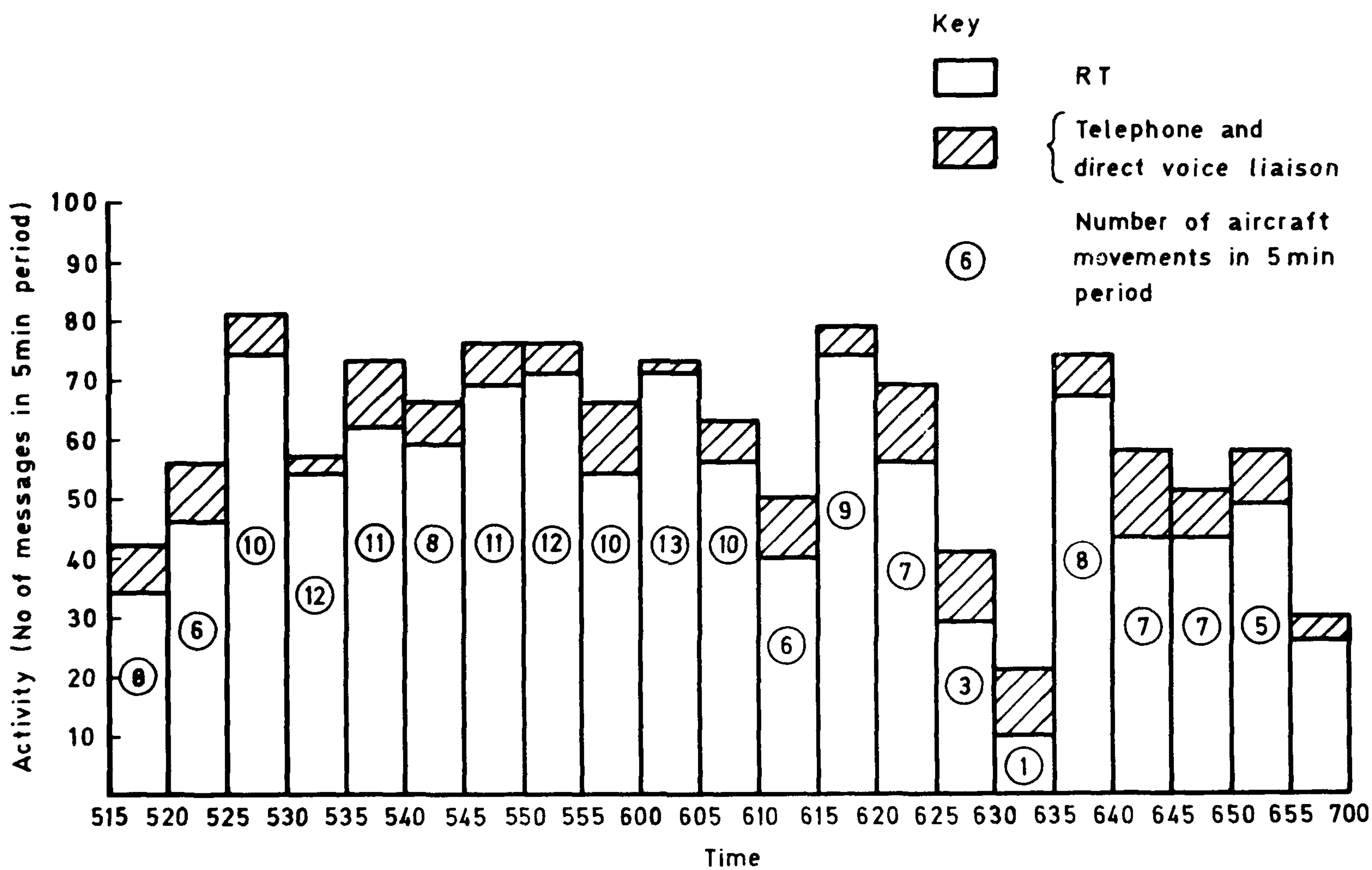

Fig 3 Activity histogram – tower position pm 6-9-78 (high activity)

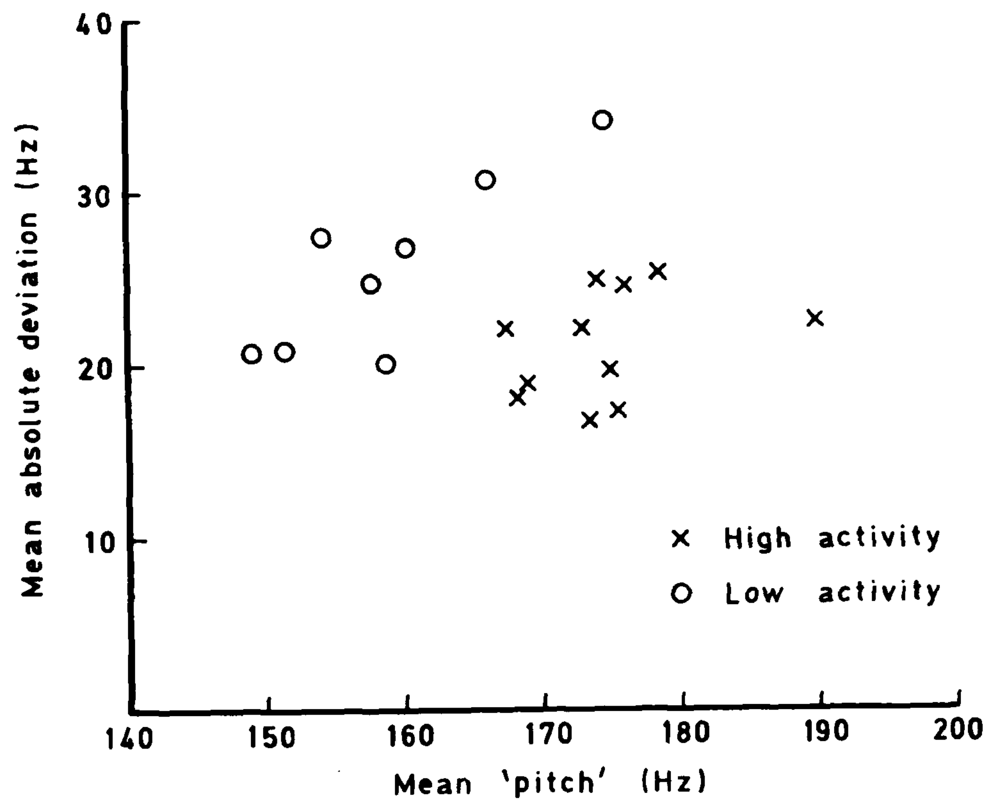

Fig 4 Scatter plot of mean pitch vs mean absolute deviation

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17. Abstract

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